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Data Requirements for Bathing Water Assessments

Discussion of the stochastic aspects

by

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Bathing water objectives

Said in a few words the EC bathing water directive requires that the concentration of the indicator bacteria (faecal coliforme or E.coli.) must not exceed the specified limit (2000 faecal coliforme bacteria per 100 ml) in more than 5 % of the time. In Denmark the limit is lower, 1000 bacteria per 100 ml.

It is essential to consider the stochastic character of this standard in the planning of a bathing water assessment for a particular long sea outfall.

Stochastic simulation of many independent situations

The experience from bathing water sampling in polluted near shore waters, shows that the probability distribution of the bacteria concentration is a very skew function, often something like the log-normal distribution. This means that the bathing water quality cannot be estimated from a characteristic "design situation" based on mean (or median) values for the relevant parameters.

From the author's point of view, the only rational way to estimate the bathing water quality on a beach is to use numerical simulations, where a large number of independent situations are simulated, incorporating some of the important parameters as stochastic variables.

Simulation of individual situation

The aim of the numeric simulation of the individual situation, is to produce an instantaneous picture of the spatial distribution of bacteria in the area. From this picture one should imagine that a number of water samples were taken on interesting points on the coast.

The concentration of bacteria on a given point along the coast can be found from the bacteria source strength multiplied with two factors, a bacterial decay factor and a transport/dispersion factor. The source strength and the two factors will vary from situation to situation.

Source strength of bacteria from sea outfalls

Only treated sewage is discharged in Denmark. Based on series of samples from outlets from different treatment plants with secondary treatment in Denmark it has been concluded that the outlet concentration of bacteria is a stochastic parameter most often with a log-normal distribution.

If the treatment plant already exists, it is recommended to set up a programme for the determination of the actual distribution of the bacteria concentration. In other cases one has to look for a similar catchment in the neighbourhood with a similar treatment and use data from here. Be aware that the high values with a relative low frequency are the most important data to get. Take more than 20 to 40 samples, e.g. one sample weekly on different times of the day respectively the week.

The source strength is the product of the concentration and flow. The flow variation daily and weekly will often be well-known, even in the design stage, and should accordingly be taken as a time dependent variable without stochastic elements.

Bacterial decay

The bacterial decay is often assumed to follow a simple first order relation giving an exponential reduction with time. The process is characterized with the parameter T_{90}, which is the timescale in wich 90 % of the bacteria die. T_{90} will depend mainly on UV-ligth (from the sun) and biological activity in the receiving waters. The order of magnitude for T_{90} seen in Denmark is 3 to 50 hours, highest in turbid water.

Unfortunately T_{90} is difficult to measure. In principle it must be found from field experiments, where the reduction of bacteria concentration are compared with the dilution of a stable tracer. Because of the variability of T_{90}, the experiment should be repeated several times to find its probability distribution. This is indeed one of the difficult, but important points in the overall problem. It is recommended to spend the necessary resources to find some reasonable numbers for this.

In a many cases T_{90} has been assumed to be a constant, which is a very rough assumption, not in balance with the effort and money used on other parts of the problem. The author has in a few cases in agreement with the responsible authorities, used a T_{90} varying stochastically with an equal distribution between a low and a high value (e.g. between 3 and 10 hours). This assumption of an equal distribution has not been experimentally verified.

Transport and dispersion of sewage plumes

The dilution process in connection with the discharge of sewage from sea outfalls will normally be an unsteady 2- or 3-dimension problem. The paper below, concerning the Monte Carlo simulation of near shore sewage plumes, is an example of one of the simplest ways to come handle such a complex problem.

In this method the governing and varying parameters are

wind force and direction
time when 'bathing water sample' is taken in relation to the tidal cycles
long shore net current
source strength of bacteria
decay factor of bacteria

In the simulation of the individual situation, each parameter should be found by the computer from a stochastic experiment taking into account the parameters probability distribution.

The analyses of computated situations

Finally the results of the many individual simulations should be analysed statistically exactly the same way as if the results had been found from real samples taken in the near shore water.